

Table C-9
Format for Budgetary Cost Estimating

Step 1. Project Dimensions
Step 2. Area Expansion Factor
Step 3. Function Ratio
Step 4. Effort Hours per 100 Acres
Step 5. Total Effort Hours
Step 6. Function Hours
• Field survey hours
• Digital mapping hours
Step 7. Hourly Labor Rates
Step 8. Direct Cost
Step 9. Total Estimated Project Cost

(8) Step 8: Direct Cost. Many of the direct cost items are relatively minimal as a single cost item. However, in the aggregate, these costs do impact the total cost. In budgetary cost estimating, a single lump

sum percentage can be applied to cover these direct costs. Two items of mapping costs are significant:

(a) Hourly rental on stereoplotter instruments, which are used to collect the digital mapping data.

(b) Hourly rental on CADD systems, which may be used in the digital data editing process.

For budgetary estimating, it is realistic to presume that half of the mapping hours will be expended on each of the systems. The estimator must make an effort to attach a reasonable fee for these factors:

(a) Negotiated contractor amortization rates.

(b) Suggested rates from equipment manufacturers.

Direct cost rates are listed in Table C-13.

(9) Step 9: Total Estimated Project Cost.

(a) Aerial photography. Table C-10 indicates the estimated costs for aerial photography. Using this table requires three parameters: map scale/CI combination (in this example, the project is to be mapped at 1 in. =

Table C-10
Estimated Budgetary Costs for Aerial Photography

Area, Acres	Cost, dollars, for			
	Distance to Site, miles			
	100	200	300	400
Use for Maps to Scale 1 in. = 50 ft with 1-ft CI Only				
1,000	1,700	2,100	2,900	6,600
3,000	2,100	2,500	3,300	7,000
5,000	2,700	3,100	3,900	7,600
Use for Maps to Scale 1 in. = 100 ft with 2-ft CI Only				
1,000	1,500	1,900	2,700	3,100
3,000	1,600	2,000	2,800	3,200
5,000	1,700	2,100	2,900	3,300
Use for Maps to Scale 1 ft = 200 ft with 5-ft CI Only				
1,000	1,400	1,800	2,600	3,000
3,000	1,500	1,900	2,700	3,100
5,000	1,500	1,900	2,700	3,100
Use for Maps to Scale 1 ft = 400 ft with 10-ft CI Only				
1,000	1,300	1,700	2,400	2,800
3,000	1,300	1,700	2,500	2,900
5,000	1,400	1,800	2,600	3,100

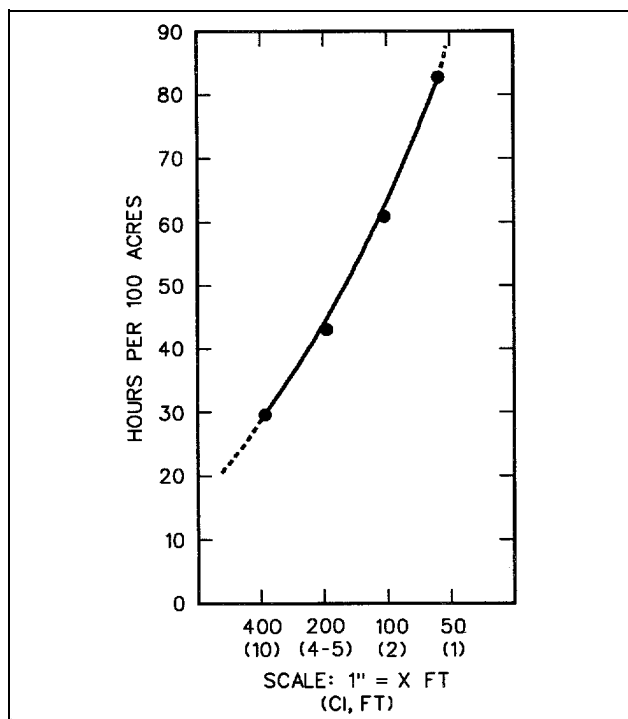


Figure C-25. Combined field survey and digital mapping hours per 100-acre block

**Table C-11
Hourly Labor Rates, Overhead, and Profit Margin for Photo Control Surveying**

Function	Maximum	Average	Minimum
Hourly Rate, \$			
Supervisory Surveyor	33.25	21.48	15.37
Party Chief	16.91	14.36	12.08
Instrumentman	13.40	11.44	9.62
Rodman	10.70	9.12	8.27
Draftsman	14.12	11.97	10.13
Computer Operator	17.80	15.75	12.24
Overhead, %	142	134	130
Profit, %	12.50	11.10	12.00

100 ft with 2-ft contours); photography area (in this example, 5,400 acres); distance from aircraft base to project site (simulated to be 150 miles for this project). Referring to the 1 in. = 100 ft/2-ft contour portion of Table C-10, the cost for flying 100 miles to photograph 5,000 acres is \$1,700 and for 200 miles is \$2,100, so a flight of 150 miles is interpolated to be \$1,900.

**Table C-12
Hourly Labor Rates, Overhead, and Profit Margin for Photogrammetric Digital Data Collection**

Function	Maximum	Average	Minimum
Hourly Rate, \$			
Chief Photogrammetrist	28.80	19.43	16.00
Photogrammetrist	21.70	16.42	13.00
Stereocompiler	15.00	11.26	8.25
Computer Operator	20.60	15.78	11.91
CADD Draftsman	13.00	10.48	8.01
Overhead, %	194	164	104
Profit, %	12.00	11.29	10.00

**Table C-13
Direct Cost Rates**

Function	Rates, \$ per U/M Indicated		
	Maximum	Average	Minimum
Aircraft	375.00/hr	254.71	170.00
CADD Workstation	20.00/hr	11.65	5.77
Analytical Stereoplotter	22.47/hr	15.54	8.60
Computer Rental	15.00/hr	9.94	6.70
B&W Contact Prints	3.00/ea	3.24	1.56
Color Contact Prints	5.10/ea	3.93	1.84
B&W Diapositives	8.00/ea	3.58	1.60
Color Diapositives	12.00/plate	5.24	2.70
CADD Data Plots	22.00/sheet	20.07	13.30

Average

Vehicle Mileage	0.25/mile
Field Survey Books	9.00/each
Stakes/Lath	11.00/bundle
Monuments	5.00/ea
Per Diem	(per Joint Travel Regulations (JTR) rate)

Aerial Film Processing Costs		Average Cost per Foot, \$	
		Film	Processing
Panchromatic	1.20	0.60	
B&W Infrared	2.10	0.60	
Color Infrared	4.20	1.60	
Natural Color	3.75	1.60	

Notes:

1. Assume 1 photo exposure = 1 ft of film.
2. On small jobs, minimum film charges usually apply.

(b) Lump sum factors. Two factors should be applied to the total production costs in order to cover costs of technical supervision and aggregate of minor peripheral operations and items. Technical supervision covers the periodic effort of nonproductive managers, such as Supervisory Surveyors, Photogrammetrists, and Project Managers. A factor of 10 percent should be realistic for budgetary estimating. Minor peripheral items and operations would be survey vehicle rental, per diem, computer rental, aerotriangulation, computer operators, drafters, lab technicians, etc. These factors can vary greatly; for this project a 10 percent factor will be used.

(c) Profit. The estimator can use negotiated contractor rates for profit margin. If these are not available, profit usually amounts to 10 percent to 12 percent of the production costs.

e. Estimating project costs.

(1) Defined Parameters.

(a) Contour interval. Table C-14 indicates appropriate CI for preliminary design is 2 ft.

Table C-14
Selection of Contour Interval

CI, ft	Purpose
1	Final Design and Earthwork Computations
2	Preliminary Design and Route Location
4-5	Preliminary Project Planning Phases

(b) Map scale. Figure C-25 indicates that the appropriate map scale for 2-ft contours is 1 in. = 100 ft.

(2) Using Table C-9 as a guide and referring to *d* above, the budgetary costs for this sample project are computed as follows:

(a) Step 1. Project Dimensions:

$$13,000 \text{ ft long} \times 18,000 \text{ ft wide} / 43,560 \text{ ft/acre} \\ = 5,400 \text{ acres}$$

(b) Step 2. Area Expansion Factor:

$$5,400 \text{ site acres} / 100 \text{ acres} = 54$$

(c) Step 3. Function Ratio: surveys 35 percent, mapping 65 percent.

(d) Step 4. Effort hours per 100 Acres (taken from Figure C-25) = 60 hr.

(e) Step 5. Total effort hours (area expansion factor \times effort hours per 100 acres) = $54 \times 60 = 3,240$ hr.

(f) Step 6. Function hours (total effort hours \times function ratio):

$$\text{Surveys} = 3,240 \times 35\% \\ = 1,134 \text{ hr}$$

$$\text{Mapping} = 3,240 \times 65\% \\ = 2,106 \text{ hr}$$

(g) Step 7. Hourly labor rates (use mean rates from Tables C-11 and C-12):

	<u>Surveys</u>		<u>Mapping</u>
Party Chief	\$14.36	Compiler	\$11.26
Instrument Worker	\$11.44	CADD Draftsman	\$10.48
Rod Person	\$ 9.12		
	-----		-----
Avg Hrly Rates	\$11.64		\$10.87

(h) Step 8. Direct cost (CADD system and analytical stereoplotter rental rates from Table C-13.)

$$\text{CADD: } 50\% \times 2,106 \text{ mapping hours} \times \$11.65 \\ \text{hourly rental} = \$12,267$$

$$\text{Analytical Plotter: } 50\% \times 2,106 \text{ mapping hours} \\ \times \$15.54 \text{ hourly rental} = \$16,364$$

(i) Step 9: Total Estimated Project Cost.

Photography:	\$ 1,900
Labor:	
Surveys (1,134 hr \times \$11.64)	\$ 13,200
Mapping (2,106 hr \times \$10.87)	\$ 22,892
Overhead:	
(mean rates from Tables C-11 and C-12)	
Surveys (\$13,200 \times 133.87%)	\$ 17,671
Mapping (\$22,892 \times 163.87%)	\$ 37,513
Direct Costs:	
CADD System	\$ 12,267
Analytical Stereoplotter	\$ 16,364

<u>Total Production Costs</u>	<u>\$121,807</u>
Supervision (@ 10%):	\$ 12,181
Peripheral (@ 10%):	\$ 12,181

<u>Subtotal</u>	<u>\$146,169</u>
Profit (12% \times \$146,169)	\$ 17,540

<u>Total Project Cost (Budgetary)</u>	<u>\$163,709</u>

C-32. Approaches to Estimating Detailed Project Costs

Detailed cost estimates are required for contract negotiation purposes. Unlike the rough budgetary estimates described in paragraph C-31, detailed estimates must specifically account for all significant cost phases of a photogrammetric mapping operation. This is necessary since these estimates (both the Government's and the contractor's) may be subject to detailed field audits and/or other scrutiny. Also, contract modifications must be able to relate to the original estimate. Initially, it is important to specify which of the activities involved in making a map will be completed by the contractor and which may be done by the Government. USACE and other agencies may do some portion of the work. Most USACE Commands, however, contract all the mapping work and do not participate in any of the actual production activities associated with the generation of digital mapping products.

a. General estimating procedure. The cost estimating procedures presented here can be used to estimate all or only certain parts of a mapping project. An "add/subtract" approach was also included to maximize the applicability of this method. This approach allows each user to develop a cost estimating method that incorporates information needed in a specific locale. It is responsive to existing expertise and equipment found within USACE commands, and it allows for exclusion of portions of a mapping project to be conducted by USACE hired-labor forces.

(1) Those using the following procedures should indicate which of these activities need to be cost estimated. Work to be omitted from the contract and performed by the Government can be excluded from this method and ignored for given project calculation of contractor costs. As stated earlier, those steps in a mapping project and in a cost estimating procedure for mapping include aerial photography, photo control surveying requirements, and map production (aerotriangulation, stereocompilation, conversion to CADD format). For each of these activities, the cost estimates have been further stratified into categories or cost elements that make up the second level of the hierarchy. Elements are grouped into costs that are based on Direct Labor, Hours, and Direct Costs. Under each second-level heading are the individual cost elements. This last "break-down" presents a third level of detail.

(2) Paragraphs C-33 through C-42 present the cost estimating procedure in its entirety. It provides the

individual cost elements or entries as a quantity (QUAN), unit measure (U/M, e.g., hours), unit price (U/P, e.g., \$/hour), and/or amount (AMOUNT) or total for item. These elements can then be summed under the appropriate cost headings (e.g., Direct Labor, Hours, or Material Costs). These cost element headings can be summed for the total, and indirect costs and profit can be calculated to arrive at estimated cost for the project at hand.

b. Labor. Amount of work and cost of work that personnel will conduct is characterized as "Direct Labor, Hours" or other unit cost. This has been done for a number of reasons:

(1) It is convenient to express work in hours because it provides a per unit cost basis for estimating purposes.

(2) Salary figures are difficult to work with as an end product, but they can be unitized by division of the annual hours of work and made useful as a "unit hourly cost" for a given activity.

(3) Surveying and mapping services often have an hourly component in cost estimating, and this hourly approach is suitable to conditions under which contracting will be conducted.

(4) Hourly costs may be obtained from prequalified contractors or from wage rate determinations.

c. Direct costs. Following the cost associated with Direct Labor or Hourly activities are costs that are direct in nature. Direct costs such as Material Costs can be easily calculated and are fixed by the number of units of a direct cost item that are required to complete the project. Typical direct cost items in large-scale aerial mapping would be the number of sheet-equivalents or feet of film that are necessary to provide photo coverage of the site.

(1) These direct costs may also be made on a per hour basis. This is the case for aircraft rental time. Therefore, it is important to realize that a number of cost items listed as either Direct or Material may be reported in hours.

(2) Direct costs may also be characterized as costs that do not have additional costs associated with their use. For example, labor costs often are associated with personnel who have benefit packages that may be charged in proportion to the time these individuals are used on the project. Direct costs may also be

characterized by the fact that certain direct cost items may not be charged with additional indirect costs.

C-33. Project Specifications

a. Variables. It is desirable to specify a number of variables to help best characterize the mapping project and to assure that an accurate and precise cost estimate can be completed. Exact numbers and types of variables can be different for alternate approaches to cost estimating. However, a complete list of possible needs can be provided, and the required specifications can be selected from the list to customize the content for each cost estimate. It is desirable to specify a set of variables that describes the project before a cost estimate is made. Such a list or set of variables is provided herein. It includes most required items, and they should be known along with other information deemed to be useful. This would include information from this manual or in the Civil Works Construction Guide Specifications 01335. The list of specifications presents a good example of what information needs to be supplied before a cost estimation is made. This list is not exhaustive and any effort may include other variables as determined by the Command employing this method.

b. Assumptions. In developing the cost estimating method used herein, certain assumptions were employed. These are important because a variety of approaches to large-scale mapping are used in Government and industry. Some approaches make use of the latest technology and mathematical solutions. Others use older technology and methods. Here, several assumptions are made about approaches and technologies to provide uniform conditions for cost estimation. The following assumptions are made:

(1) Analytical stereoplotters will be used. For calculations the maximum C-factors for these instruments are noted in Table 2-7.

(2) Aerotriangulation spans the number of stereo-models in accordance with Table 6-1. Hence, "skeletal" field control survey procedures will be in effect.

(3) Cost per hour of personnel can be obtained from wage rates or from negotiated information supplied by the contractor.

C-34. Contract Parameters

It is necessary to have information for the following items to best specify a project. Many of the items listed below are inputs to the cost estimating procedure and are used in calculations of parameters.

a. Area to be mapped. It is desirable to provide a firm definition of the area to be mapped. This may be shown on large-scale topographic maps or 1:24,000 USGS quadrangles. Other descriptive and measurement information should be provided if available. Information may include details from surveys, deeds or whatever other documents are available. Descriptions may also include gross north-south and east-west dimensions of project.

b. Parameters. Other mapping parameters should be specified and may include the following:

- (1) Final map scale.
- (2) CI.
- (3) Photo scale.
- (4) Flight height above mean ground level.
- (5) Film type.
- (6) Calibrated focal length of camera.
- (7) C-factor of stereoplotter.
- (8) Nominal endlap.
- (9) Nominal sidelap.
- (10) Distance from aircraft base to project site.
- (11) Flight line distance.
- (12) Distance from site to nearest established horizontal control reference.
- (13) Distance from site to nearest established vertical control reference.
- (14) Cruising speed of aircraft.

(15) Estimate of terrain slope variability.

(16) Estimate of cultural development variability.

c. Deliverables. A list of delivery items should be supplied. This is necessary to clearly define the end products, which should ensure an accurate estimate of cost. The list below consists of a number of possible products that may be requested. Products should be specified by including them in the list. Also state the number of copies or sets to be furnished.

(1) Contact prints.

(2) Map sheets.

(3) Digital data in CADD or GIS/LIS format.

(4) Photo enlargements.

(5) Photo index.

(6) Photo mosaics.

(7) Field surveys.

(8) Orthophotos.

C-35. Calculated Parameters

There are several project-specific parameters that must be determined prior to cost estimating. This information is necessary to characterize the project and to supply input for the solution of individual line items.

a. Photo scale.

b. Number of flight lines.

c. Location of flight lines.

d. Number of flight line miles.

e. Number of photo exposures.

f. Flight height.

g. Acres of area to be mapped.

C-36. Cost Estimating Elements

The elements of the cost estimating procedure described in this appendix are outlined in paragraphs C-37 through

C-39 below. These three categories cover aerial photography, control surveys, and digital map compilation. The format used begins with detailed specifications for the individual contract effort. "Direct Labor, Hours" cost elements are provided as subheadings. "Material Costs" are addressed to complete the list of items that are to be used in costing photogrammetric mapping and aerial photographic services.

C-37. Aerial Photography Cost Items

Planning an aerial photo mission is important, because the resultant imagery impacts the accuracy of the final products. The following items are to be specified to assist in the calculations of costs associated with aerial photography.

a. Aircraft transport distance to site and return.

b. Aircraft speed.

c. Aircraft cost (charge per flight-hour).

d. Number of flight line miles.

e. Flight height above mean ground level.

f. Nominal photo scale.

g. Project size:

(1) Acres to be mapped.

(2) Gross dimensions to be photographed.

h. Contractor costs or wage rates (cost per hour). When using the formats in paragraphs C-37 through C-39, the estimator should enter the hourly labor rate for a specific technician in the "\$/hour" slot. The estimator should make every effort to ensure that these rates are regional wage rates or actual contractor negotiated rates, as would be the case for work orders placed against an IDT contract. The following types of technicians would be used on a photomapping contract:

(1) Pilot and photographer on flight crew.

(2) Photo lab technician to check and title film as well as produce photo reproductions, and lay mosaics and photo indexes.

(3) Party chief, instrument worker, and rod person on field control survey crew.

(4) Drafter to make traverse diagrams, sketches, and references.

(5) Survey computer to balance traverses and level loops.

(6) Photogrammetrist to directly supervise mapping effort.

(7) Stereocompiler to collect digital mapping data.

(8) Editor/Drafter to edit digital mapping data.

(9) Computer operator to translate and manipulate digital mapping data for delivery products.

i. Itemization of labor cost items for aerial photography.

ITEM/DESCRIPTION	QUAN	U/P	AMOUNT
Labor required for flight planning (Pilot):	___ hr	\$___/hr	\$___
Labor for ground crew preparations prior to flight (U/M = Crew Hours (C-hr))	___ C-hr	\$___/C-hr	\$___
Inroad flight crew time (airfield to site)	___ C-hr	\$___/C-hr	\$___
Time of photography (Flight crew)	___ C-hr	\$___/C-hr	\$___
Film checking labor (quality check and titling)			
Lab technician	___ hr	\$___/hr	\$___
Labor: Project Manager	___ hr	\$___/hr	\$___
<u>Total Labor (Aerial Photography):</u>			\$___

j. Itemization of direct costs for aerial photography:

ITEM/DESCRIPTION	QUAN	U/P	AMOUNT
Aircraft Operation: Flight time to site (flight hours = miles to site times 2/average aircraft speed in mph) (U/M = Flight Hours (F-hr))	___ F-hr	\$___/F-hr	\$___
Photography time	___ F-hr	\$___/F-hr	\$___
<u>Total aircraft rental/charge</u>			\$___
Film	___ exp	\$___/exp	\$___
Film Processing	___ exp	\$___/exp	\$___
Contact Prints			
(___ exp × ___ sets) ___ prints		\$___/print	\$___
<u>Total Direct Costs (Aerial Photography):</u>			\$___

C-38. Photo Control Surveying Cost Items

a. Offsite information. The following items are to be specified to assist in the calculations of costs associated with photo control surveying.

(1) Distance from survey office to site.

(2) Distance to horizontal reference.

(3) Distance to vertical reference.

(4) Time to complete horizontal photo control or number of points required.

(5) Time to complete vertical photo control or number of points required.

b. *Itemization of labor costs for photo control surveys.*

ITEM/DESCRIPTION	QUAN	U/P	AMOUNT
Survey party labor (party chief, instrument worker, rod person):			
Inroad travel: ___hr/trip × ___trips = ___C-hr (U/M)			
	___ C-hr	\$___/C-hr	\$___
Reconnaissance	___ C-hr	\$___/C-hr	\$___
Transfer referenced control to site:			
Horizontal ties	___ C-hrs	\$___/C-hr	\$___
Vertical ties	___ C-hr	\$___/C-hr	\$___
Horizontal control	___ C-hr	\$___/C-hr	\$___
Vertical control	___ C-hr	\$___/C-hr	\$___
Set photo targets	___ C-hr	\$___/C-hr	\$___
Office computations	___ hr	\$___/hr	\$___
Sketches & references	___ hr	\$___/hr	\$___
Project manager labor	___ hr	\$___/hr	\$___
<u>Total Labor Costs (Surveys):</u>			\$___

c. *Itemization of direct costs for photo control surveys.*

ITEM/DESCRIPTION	QUAN	U/P	AMOUNT
Target material	___targets	\$___/ea	\$___
Per Diem (___crewmen × ___survey days = ___days)			
	___days	\$___/day	\$___
Vehicle mileage (Inroad: ___ miles round-trip × ___ trips = ___miles)			
	___miles	\$___/mile	\$___
Local	___miles	\$___/mile	\$___
<u>Total Direct Costs (Photo Surveys)</u>			\$___

C-39. Photogrammetric Compilation and Digital Mapping Cost Items

a. *Site specific information.* The following items are to be calculated, estimated, or measured to assist in the computing costs associated with digital mapping.

- (1) Number of stereomodels to orient.
- (2) Number of acres to map.
- (3) Complexity of terrain character.
- (4) Complexity of planimetric culture.
- (5) Format translations of digital data.

b. *Itemization of labor costs for digital mapping.*

ITEM/DESCRIPTION	QUAN	U/P	AMOUNT
Photo control planning	___ hr	\$___/hr	\$___
Photo control input	___ hr	\$___/hr	\$___
Stereomodel orientation	___ hr	\$___/hr	\$___
Stereocompilation Labor			
Planimetric (___ models (or acres) × ___ hours per model (or acre) = ___ hours)			
	___ hr	\$___/hr	\$___
Topographic (___ models (or acres) × ___ hours per model (or acre) = ___ hours)			
	___ hr	\$___/hr	\$___
Digital data editing (___% of ___ total hours stereocompilation = ___ hours)			
	___ hr	\$___/hr	\$___
Digital data transformation or translation			
	___ hr	\$___/hr	\$___
Project manager labor	___ hr	\$___/hr	\$___
<u>Total Labor Costs (Digital Mapping)</u>			\$___

c. Itemization of direct costs for digital mapping

ITEM/DESCRIPTION	QUAN	U/P	AMOUNT
Contact prints (control photos)	__ prints	\$___/print	\$___
Diapositives	__ plates	\$___/plate	\$___
CADD System Usage	__ hr (min)	\$___/hr (min)	\$___
Analytical Stereoplotter System Utilization	__ hr (min)	\$___/hr (min)	\$___
Data Plots:			
Preliminary (2 sets)	__ sheets	\$___/sheet	\$___
Final	__ sheets	\$___/sheet	\$___
Aerotriangulation	__ models	__\$/model (photo)	\$___
<u>Total Direct Costs (Digital Mapping)</u>			<u>\$___</u>

C-40. Summary of Photomapping Costs

Listed below is a summary of the costs itemized in paragraphs C-37 through C-39 with applied overhead and profit margins to accumulate a total project cost.

Labor Costs:

Aerial Photography	\$___
Photo Control Surveying	\$___
Digital Mapping	\$___
<u>Total Labor Costs</u>	<u>\$___</u>

**General and Administration
(G&A) Overhead**

(Total Labor × Overhead Rate) \$___

Direct Costs

Aerial Photography	\$___
Photo Control	\$___
Digital Mapping	\$___
<u>Total Direct Costs</u>	<u>\$___</u>

Total Project Costs

(Hourly Labor + Overhead + Direct) \$___

Profit

(Total Project Costs × Profit Margin) \$___

Total Estimated Project Cost \$___
(Total Project Costs + Profit)

C-41. Cost Estimating Aids

To support the process of estimating hours and direct costs of various photomapping phases, several estimating guidelines are included. These estimating guidelines are based on 1991 production measures and average labor costs. Maximum, average, and minimum direct labor charges are provided for each position function, based on the sample of firms indicated. Likewise, maximum, average, and minimum overhead rates and profits are shown. The overhead rate indicated includes direct fringes and G&A. It must be emphasized that these rates are taken from a relatively small sample of firms spread over CONUS, which accounts for their wide ranges. The estimator, when costing an authentic project, is urged to seek current labor rates more applicable to a project or geographical area, perhaps using regional wage rates or actual negotiated contractor rates from recent or current contracts. Although all of these estimating tools may not be suitable for every project, some may fit particular sites, or perhaps may be a catalyst to develop regional estimating tools tailored to a particular USACE Command.

a. Contour interval. Table C-14 indicates appropriate CI's for various types of projects. Refer also to Tables 2-4 and 2-5 for additional functional applications.

b. Aerial photography hourly labor rates. Table C-15 is a recap of 1991 labor rates for seven geographically distributed private sector aerial photographers. These wage rates may be used for general estimating purposes when specific local rates are not available.

c. Photo control surveying hourly labor rates. Table C-11 is a recap of 1991 rates of five geographically scattered private sector surveying firms covering typical field survey services.

d. Digital mapping hourly labor rates. Table C-12 is a recap of 1991 rates of seven geographically

Table C-15
Hourly Labor Rates, Overhead, and Profit Margin for Aerial Photography

Function	Maximum	Average	Minimum
Hourly Rate, \$			
Project Manager	33.18	24.08	18.20
Pilot	18.20	15.42	12.07
Photographer	15.50	13.00	8.84
Lab Technician	14.00	10.84	8.84
Overhead, %	194	164	104
Profit, %	12.00	11.29	10.00

scattered private sector aerial mappers, covering various compilation and mapping services. Functions of these individuals will include the following:

(1) Chief Photogrammetrist: concerned primarily with administrative duties, project management, client liaison.

(2) Photogrammetrist: involved in production management and technical trouble shooting.

(3) Stereocompiler: operates stereoplotter in digital mapping production. He may also do some portion of aerotriangulation such as control planning, point pugging, and plate coordinate collection.

(4) CADD Drafter: does digital data editing on a type of CADD system. He does not necessarily need to be as experienced as a stereocompiler.

(5) Computer Operator: does digital data translation, transforming, and massaging, as well as computer operation relative to aerotriangulation.

e. Aerotriangulation rates. Rather than itemize cost for aerotriangulation operations, most mappers charge a flat fee for this function—usually \$70-\$80 per photo at 1991 rates. In the event that it is necessary to devise a cost breakdown for control bridging, Table C-16 may be used for guidance.

f. Direct cost rates. Table C-13 recaps primary direct cost items.

Figure C-26 indicates the cruising speed of aircraft relative to hourly rental fee. Once speed is determined, aircraft flight hours can be calculated.

g. Stereocompilation hours.

Table C-16. Breakdown of Operations to Calculate Aerotriangulation Time Requirements

Function	Hours per Model
Planning, Point Selection, and Labeling	0.50
Photo Point Pugging	0.50
Comparator Plate	
Coordinate Reading	0.35
Computer Input, Preparation, and check	0.25
Computer Computations	0.35

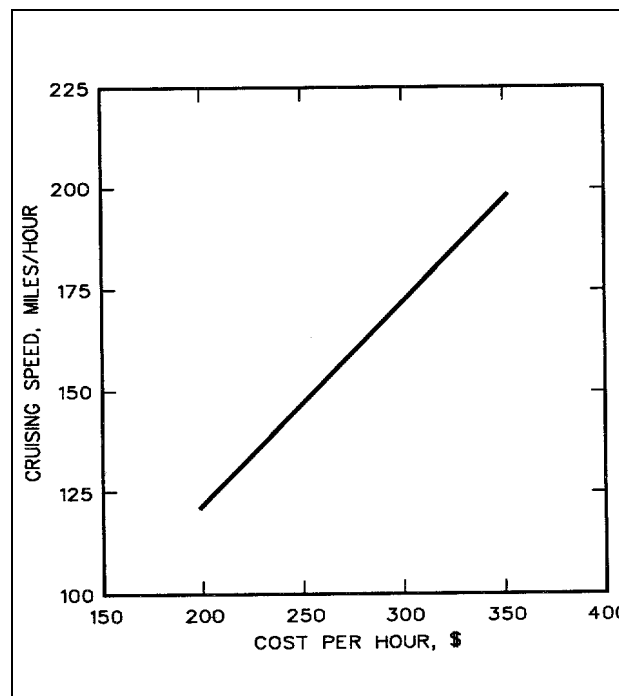


Figure C-26. Estimating aircraft cruising speed costs

(1) Model setup. Stereomodel orientation times normally run about half-hour per stereomodel.

(2) Data digitizing. Figures C-32 through C-35 (paragraph 44I) may be used as aids in estimating planimetric and topographic digitizing effort.

h. Digital data edit. Digital data editing time can range between 50-100 percent of digital data collection time depending upon the production routine of specific mapping units and quantity and complexity of mapping information.

C-42. Planning and Costing Photogrammetric Digital Mapping Projects

Procedural planning and item costing on several example projects will follow. In these examples, the formula approach is emulated such that every item that is required to accomplish the production goal will be considered and costed. These examples are designed so that the potential estimator will become familiar with the entire estimating procedure and format.

a. The estimator, on actual projects, need not follow these formats by rote. He may pick and choose those functions that match specific project or locale requirements, and discard or revise those that are not appropriate. As discussed earlier, hourly labor rates, direct cost item rates, overheads, and profit margins used in these examples vary significantly between individual production organizations.

b. Production costs can vary significantly between geographical regions. When estimating costs for authentic projects, the estimator should seek specific procedures, historical production time estimates, hourly rates, overhead, profit margin, and direct item costs in order to tailor the costing to local experience and specific needs.

Section III Sample Photomapping Cost Estimates

C-43. Exercise Number 1: Aerial Photo Mission For Photo Analysis Purposes

a. *Project.* This mapping project is designed to assess stressed areas of crops in midgrowing season. The site is outlined on the map in Figure C-27, which is taken from a portion of a 1:250,000 USGS quadrangle.

b. *Requirements and procedures.*

(1) Obtain aerial photography that assures image discrimination between healthy and possibly distressed areas of crops.

(2) Analysts will use the imagery to locate areas of dead or unhealthy crops, and distinguish between corn and beans.

(3) Analysts will go to the field to sample a number of areas to ascertain the veracity of the image interpretations.

(4) Using existing base map sheets, analysts will transfer photo delineations to this mapping.

(5) Analysts will then measure areas from the map and compile a report of their findings.

Items (2) through (5) are not pertinent to cost estimating the mapping work. They are included only to show how the aerial photography fits into the overall project.

c. *Film.* It is decided to fly color infrared (false color) aerial photography because it allows interpreters to differentiate between healthy and distressed areas of vegetation. Color infrared has at least three processing options:

(1) Film can be processed to a negative. The user may then order contact prints or transparencies to use in the interpretive work.

(2) Film can be processed directly to a color transparency. The user may then work with the image on a film positive over a light table. This is the least expensive option.

(3) Film can be processed to a transparency. The user can work with the film for image analysis. Also, paper prints can be made by going through an internegative.

Although the most expensive of the three procedures, option (3) is chosen for this example. The film positives can be used in the office for interpretive work, and the paper prints are more convenient to take to the field for ground truth verification.

d. *Camera.* Standard 6-in. focal length camera.

e. *Photo scale.* Fly for a photo scale of 1 in. = 840 ft, which will allow discrimination between crops and other vegetation.

f. *Season.* Mid-June to early July would be the most advantageous time to expose photography for this particular purpose.

g. *Overlap.* Normal endlap (60 percent) and sidelap (30 percent) will be used.

h. Relevant parameters.

(1) Flight height. The altitude of the aircraft (above mean ground level) will be:

$$\frac{1 \text{ in.}}{\text{scale}} = \frac{\text{focal length}}{\text{flight height}}$$

then

$$\frac{1 \text{ in.}}{840 \text{ ft}} = \frac{6 \text{ in.}}{\text{flight height}}$$

then, flight height = $6 \times 840 = 5,040$ ft above mean ground.

(2) Overlap gains. Image area of an aerial photograph measures 9 x 9 in. With a photo scale of 1 in. = 840 ft, the total image would be 7,560 ft square. Then:

(a) Assuming normal 60 percent endlap, the length of gain between photo centers along the line of flight would be:

$$(100\% - 60\%) \times 7,560 = 3,024 \text{ ft}$$

(b) Assuming normal 30 percent sidelap, the length of gain between flight strip centers would be:

$$(100\% - 30\%) \times 7,560 = 5,292 \text{ ft}$$

i. Flight lines.

(1) Fly lines in north/south direction.

(2) Note that the flight lines will be a mile apart. The nature of this project places the site in a rural setting where the Public Land Subdivision System lines will be apparent for pilot to steer on section or quarter-section land lines.

(3) Measurements from the project map define that the area to be photographed covers a maximum area measuring 32 miles north-south by 25 miles east-west. The number of flight lines will be:

$$\frac{\text{total width}}{\text{sidelap gain}} = \frac{25 \text{ miles}}{1 \text{ mile}} = 25 \text{ flight lines}$$

j. Number of photos. All of the flight lines are essentially the same length, and each flight line will require the following number of photos:

$$\begin{aligned} \frac{\text{length of line}}{\text{endlap gain}} + 1 \text{ end exposure} \\ = \frac{32 \text{ miles}}{0.57 \text{ mile per photo}} + 1 \\ = 58 \text{ photos} \end{aligned}$$

Total exposures:

$$\begin{aligned} \text{number of lines} \times \text{number of photos per line} \\ = 25 \text{ lines} \times 58 \text{ photos} = 1,450 \text{ exposures} \end{aligned}$$

k. Cross-country. In order to estimate costs of an aerial photo mission, two elements must be determined:

(1) Distance from the site where the aircraft and crew are based to the project site. This can be measured from a road atlas.

(2) Speed of aircraft. Figure C-26 indicates that the anticipated aircraft speed is relative to the hourly rental of the aircraft once hourly aircraft rental rate is known.

l. Costing photo mission. For this project the mean values depicted in Tables C-13 and C-15 will be employed.

(1) Ground Preparation. Prior to each day's flight the pilot and photographer must prepare the aircraft and camera for flying. This amounts to about one hour per day.

(2) Photo mission time. Table C-13 indicates an aircraft rental rate of about \$255. Inserting this value into the line graph in Figure C-26 results in a cruising speed of 150 miles per hour.

(a) Photography:

$$\text{Flight lines} = \frac{25 \text{ lines} \times 32 \text{ miles per line}}{150 \text{ mph}} = 5.3 \text{ hr}$$

$$\text{End turns} = \frac{25 \text{ lines} \times 3 \text{ min}}{60 \text{ min}} = 1.3 \text{ hr}$$

$$\text{Total photography} = \text{flight lines} + \text{end turns} = 6.6 \text{ hr}$$

The flight is scheduled for the middle of June, which is the time of highest sun angle (the time of the solstice), which should allow for long flying days. This implies that the project could be flown in a single day. On the other hand, this site is located in the Midwest where, at this time of year, clouds tend to accumulate during the day. Also there are extended periods that are not conducive to flying, especially to photograph a color image. It is judged that it may take parts of two flying days of 3.3 hr each to complete the project.

(b) En route (assume for this project that the aircraft is hangared 150 miles from the project):

$$\frac{150 \text{ miles} \times 2 \text{ ways}}{150 \text{ mph}} = 2.0 \text{ hr}$$

(c) Daily flying time:

5.3 hr for each of 2 days

(d) Refueling. Since the aircraft must refuel periodically (a variable item that must be adjusted for a specific aircraft used), set the aloft time limit to 4 hr, as it would be in the interest of crew safety to allow for a refueling stop.

Refuel Stop = 1 hr each of 2 days

(e) Adjusted Flying Time =

$$6.3 \text{ hr} \times 2 \text{ days} = 12.6 \text{ hr}$$

(3) Photo lab work.

(a) Film handling. Since false color comes on 200-ft rolls, this project will require at least seven rolls of film. Once film is exposed and processed, the accuracy of the flight line alignment, degree of crab, quality of image, and overlaps are checked by the contractor. Also the

appropriate titling is stamped onto the film. Four hours per roll of film are allowed for this project.

(b) Photo reference/index map. On a project requiring this magnitude of photography, a systematic reference index of the photo coverage is in order. This can be either a flight line index or a photo index.

(c) Flight line index. The flight line centers are drawn on an existing map source (124,000, 1:50,000, 1:100,000, 1:250,000 USGS quadrangles can be used). Centers and identification numbers of the end photos, plus an appropriate scattering along the line, are spotted directly on the map. This is a relatively inexpensive procedure requiring a limited amount of labor-intensive activity. In many situations this product will suffice in locating specific photos covering selected areas. The following procedure will be used in this example: procure a set of 1:50,000 USGS quadrangles covering the area, draw each flight center on quad, and spot approximate center of every fifth photo on the flight lines. Estimated time for preparing this type of index is 16 hr.

(d) Photo index. A set of contact prints is laid out on a flat surface with each full photo manually placed and secured in its relative position with the titling information visible. A photograph is then exposed of this assemblage, usually at a scale reduction. This method is quite labor intensive and significantly more expensive than the flight line index discussed in (c) above. It will not be used or estimated in this example.

m. Production hours for aerial photography.

Phase	Pilot	Photographer	Lab Tech	Aircraft
Flight Plan	4.0			
Ground Prep	2.0	2.0		
En Route	4.0	4.0		4.0
Photography	6.6	6.6		6.6
Refuel	2.0	2.0		2.0
Check/Title				
Film			28.0	
Line Index			16.0	
Total	18.6	14.6	44.0	12.5

n. Cost of aerial photography.

(1) Salaries. Use mean hourly rates from Table C-15.

Personnel	Hours	Rate	Cost
Pilot	18.6	\$15.42	\$ 287
Photographer	14.6	\$13.00	\$ 199
Lab Tech	44.0	\$10.84	\$ 477
Supervision (10% of Others' Hours)	8.0	\$24.08	\$ 193
Hourly Rate Costs			\$1,156
Overhead on Labor (163.87%)			\$1,894
Total Labor Cost			\$3,050

(2) Direct costs. Use mean item rates from Table C-13.

Direct Cost Item	Units	Unit Cost	Cost
Aircraft	12.5	\$255.00	\$ 3,600
Contact Prints	1,450.0	\$ 6.00	\$ 8,700
Aerial Film	1,450.0	\$ 4.20	\$ 6,090
Film Processing	1,450.0	\$ 1.60	\$ 2,320
Total Direct Cost			\$20,710

(3) Total estimated costs.

Labor	\$ 3,050
Direct	\$20,710
Subtotal	\$23,760
Profit (11.29%)	\$ 2,682
Total Cost	\$26,450

C-44. Exercise Number 2: Digital Mapping Project Cost Estimate

a. Project. The scope of this project involves Class 2 mapping for preliminary site plan design mapping on a community development project. The site covers the area shown on the map in Figure C-28, which is taken from a portion of a 1:24,000 USGS quadrangle.

b. Procedure. As the estimating process for this project progresses, it will become evident that the following functions will be required.

- (1) Acquire aerial photography.
- (2) Accomplish skeletal field control surveys.
- (3) Generate photo control with aerotriangulation.
- (4) Collect and edit digital mapping data.

c. Defined parameters. At this point, a number of parameters can be defined:

(1) Contour interval. Table C-14 (or Table 2-5) indicates appropriate CI for preliminary design is 2 ft.

(2) Camera. A 6-in. focal length camera will be used.

(3) Photo control. The mapping area is predominantly undeveloped so identification of sufficient photo control points that could be selected on the image is limited. Hence, aerotriangulation is indicated. Class 2 mapping limits analytical photo control bridging spans (Table 6-1) to three models for vertical and five models for horizontal.

(4) C-factor. The mapper has access to an analytical stereoplotter. Class 2 mapping limits the C-factor for an analytical stereoplotter to a maximum of 2200 (Table 7-1). Since aerotriangulation will be performed, a deformation in the vertical accuracy of the bridged photo control points can be expected. Allow for a 5 percent accuracy degradation for each of the three models spanned. The revised C-factor ratio will then be $2200 \times (100\% - 15\%) = 1870$.

(5) Photo scale. This project requires a photo scale no smaller than:

$$\text{Flight Height} = \text{C-factor} \times \text{CI} =$$

$$1870 \times 2 = 3,740 \text{ ft}$$

$$\text{Photo Scale} = \frac{\text{flight height}}{\text{focal length}} = \frac{3740}{6}$$

$$= 623 \text{ or } \underline{1 \text{ in.} = 623 \text{ ft}}$$

(6) Mapping scale. Class 2 mapping allows for a maximum image enlargement factor, from photo negative scale to target map scale, of 8 times (Table 2-6) for planimetric features. Hence, the largest map scale allowable from the 1 in. = 623 ft photos will be:

$$\frac{\text{map scale denominator}}{\text{enlargement factor}} = \frac{623}{8} = 77 \text{ or } \underline{1 \text{ in.} = 77 \text{ ft}}$$

Since this is an odd scale, the nearest smaller common mapping scale suitable for this project will be 1 in. = 100 ft .

(7) Overlap. The image area on a standard aerial photograph measures 9 x 9 in. With a photo scale of 1 in. = 623 ft, the total image will measure 5,607 ft square. Then:

(a) Assuming normal 60 percent endlap, the length of gain between photo centers along the line of flight would be:

$$(100\% - 60\%) \times 5,607 \text{ ft} = 2,243 \text{ ft}$$

(b) Assuming normal 30 percent sidelap, the length of gain between flight strip centers would be:

$$(100\% - 30\%) \times 5,607 \text{ ft} = 3,925 \text{ ft}$$

(8) Flight lines. Measurements from the project site map (Figure C-28) define an area to be photographed that covers a maximum area 18,000 ft north-south by 13,000 ft east-west. The number of flight lines are then computed:

$$\frac{\text{total width}}{\text{sidelap gain}} = \frac{13,000}{3,925}$$
$$= 3.3 \text{ flight lines (use 4)}$$

Three flight lines would not sufficiently cover this project. Since four flight lines are required, the estimator can elect to recalculate a larger photo scale to better accommodate four lines. This would allow for a larger photo scale, which would increase the accuracy safety factor. On many projects, this is an option that the estimator should seriously consider. This computation involves working backward to determine the photo scale, as shown below:

(a) Distance between flight line centers:

$$\frac{\text{total project width}}{\text{number of flight lines}} = \frac{13,000 \text{ ft}}{4}$$
$$= 3,250 \text{ ft}$$

(b) Total ground coverage per photo width:

$$\frac{3,250 \text{ ft}}{(100\% - 30\%)} = 4,643 \text{ ft}$$

(c) Photo scale:

$$\frac{4,643 \text{ ft}}{9 \text{ in.}} = 516 \text{ or } \underline{1 \text{ in.} = 516 \text{ ft}}$$

(d) Flight height:

photo scale denominator \times focal length =

$$516 \times 6 = \underline{3,096 \text{ ft}} \text{ above mean ground elevation}$$

(e) C-factor: $\frac{\text{flight height}}{\text{CI}}$

$$= \frac{3,096 \text{ ft}}{2 \text{ ft}} = 1548$$

(which would allow a greater vertical accuracy than a C-factor of 1870)

(f) Enlargement factor:

$$\frac{\text{photo scale denominator}}{\text{map scale denominator}} = \frac{516}{100 \text{ ft}} = 5.16$$

(which would allow a greater horizontal accuracy than an enlargement factor of 6.23)

Conversely, the larger photo scale will create some additional labor in performing field surveys, aerotriangulation, and model orientation. Alone, none of these items is a major cost factor, but lumped together they may be an economical consideration that should be evaluated by the estimator. In order to maintain continuity in this example cost estimate, the parameters already calculated above will be used. Figure C-24 shows the flight line layout for 1 in. = 623 ft scale photography.

(9) Number of models and photos. To calculate the number of models per flight line, simply divide total length of flight line by endlap gain:

$$\begin{aligned} \text{total models} &= \text{flight lines} \times \frac{(\text{line length})}{\text{endlap}} \\ &= 4 \times \left(\frac{18,000}{2,243} \right) = 32 \text{ models} \end{aligned}$$

Allowing one additional photo for each line to assure stereoscopic coverage results in a total of 36 photo exposures required for the project. Often, two additional photos at the end of each flight line are specified; however, in practice, only one is necessary.

d. Estimating photo mission time.

(1) Ground preparation. Prior to each day's flight the pilot and photographer must prepare the aircraft and camera for flying. This amounts to about one hour per day.

(2) Flying time. Table C-13 indicates an aircraft rental/charge rate of about \$255. Inserting this value into the line graph in Figure C-26 results in a cruising speed of 150 miles per hour.

(a) Photography. It should take no more than half an hour to fly the four flight lines in this project.

(b) En route flight time. Assume for this project that the aircraft is hangared 150 miles from the project:

$$\frac{150 \text{ miles} \times 2 \text{ ways}}{150 \text{ mph}} = 2.0 \text{ hr}$$

(c) Project flight time = 2.5 hr

This flight can be completed in one day and its duration would not require refueling.

(3) Photo laboratory work. Checking and titling film should not exceed about 2 hr for this project.

e. Production hours for aerial photography.

Phase	Pilot	Photographer	Lab Tech	Aircraft
Flight Plan	1.0			
Ground Prep	1.0	1.0		
En Route	2.0	2.0		2.0
Photography	0.5	0.5		0.5
Processing			2.0	
Total	4.5	3.5	2.0	2.5

f. Cost of aerial photography.

(1) Salaries. Use mean hourly rates from Table C-15.

Personnel	Hours	Rate	Cost
Pilot	4.5	\$15.42	\$ 69
Photographer	3.5	\$13.00	\$ 45
Lab Tech	2.0	\$10.84	\$ 22
Supervision (10% of Others' Hours)	1.0	\$24.08	\$ 24
Hourly Rate Costs			\$ 160
Overhead on Labor (163.87%)			\$ 262
Total Labor Cost			\$ 422

(2) Direct costs. Use mean item rates from Table C-13.

Direct Cost Item	Units	Unit Cost	Cost
Aircraft	2.5	\$255.00	\$ 638
Contact Prints (2 sets)	52.0	\$ 3.00	\$ 156
Aerial Film (Panchromatic)	26.0	\$ 1.20	\$ 31
Film Processing	26.0	\$ 0.60	\$ 16
Total Direct Cost			\$ 841

(3) Aerial photography costs.

Labor	\$ 442
Direct	\$ 841
Subtotal	\$1,283
Profit (11.29%)	\$ 145
Cost of Aerial Photography	\$1,428

g. Field control surveys. Costing field surveys is an individual concept. The estimator must draw upon some personal knowledge of survey procedures. Lacking that, it would be well for the estimator to sketch a diagram of anticipated control points, then confer with an

experienced surveyor to estimate the expected survey hours. Defined parameters for control surveys are as follows.

(1) En route travel. Assume for this project that the office of the field surveyor is located 100 miles from the project. This equates to about half a day per crew member for each roundtrip. Crews return to the office periodically, as dictated by the policy of the surveyor. This project will require that the crew return to the home base at least once during the performance of the survey.

(2) Site reconnaissance: 8 hr per crew member

(3) Set targets. After control point locations are established and referenced, the survey crew will lay targets over the control points. It is estimated that half an hour per target per crew member will be necessary for a target time of 10 hr per crew member. On the map in Figure C-29 are designated proposed locations of preflight ground targets. Horizontal coordinates are required on the points symbolized with a triangle, and elevations are needed on points symbolized by circles. Refer to Figure C-24 to visualize how targets relate to flight lines.

(4) Offsite control references. For this project it is assumed that there is an established triangulation station within 2 miles of the project site. A closed traverse should be run from the station to the site, then closed back on the station. The time required for a horizontal survey would be:

$$2 \text{ miles} \times 8 \text{ hr} = 16 \text{ hr per crew member}$$

The quadrangle notes a benchmark near the northeast corner of the project and another in the town near the southeast corner. A check of the Government control records verifies the existence of these stations, so there is no need to go further to tie into the vertical datum. Had these reference points not been there, the next closest benchmark is located on Highway 61 about 3 miles to the north. It would have been necessary to run a closed level circuit from this station to the project, then close back on the same benchmark, requiring about 3 days to establish this reference. Vertical surveys should be accomplished by differential leveling to third-order standards. No time needs to be allowed for a vertical survey.

(5) Horizontal traverses. The triangles shown on the target diagram in Figure C-29 indicate that there are 11 peripheral points for which coordinates will be established. Each must be included in a closed horizontal traverse initiated and closed on known monuments. The time required would be:

$$11 \text{ targets} \times 8 \text{ hr} = 88 \text{ hr per crew member}$$

(6) Vertical circuits. For each of the horizontal points in the preceding paragraph, an elevation must also be obtained. The circles shown on the target diagram in Figure C-29 indicate that there are 10 additional points for which elevations will be established. Each of the 21 vertical points must be included in a closed level circuit initiated and closed on known benchmarks. Given measurements of the distances from target to target and closing back the circuit yields a requirement for vertical loops totaling an equivalent of at least 21 miles. The time required would be:

$$\frac{21 \text{ miles}}{2 \text{ miles daily}} \times 8 \text{ hr} = 84 \text{ hr per crew member}$$

h. Production hours for field control surveys.

Phase	Party Chief	Instr Worker	Rod/ Chain	Comp Oper	Drafts-person
Travel	16	16	16		
References					
Horizontal	16	16	16		
Vertical	--	--	--		
Reconnaissance	8	8	8		
Control Surveys					
Horizontal	88	88	88		
Vertical	84	84	84		
Targets	10	10	10		
Computations				16	
Sketches					16
Total	222	222	222	16	16